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SCAB INFECTION MANAGEMENT ON APPLE LEAVES IN WESTERN BALKANS

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ABSTRACT. The disease of apple scab caused by the pathogen of *Venturia inaequalis* is a nonstop issue to the apple cultivators. The infection requires prompt and persistent treatment so as to control the infection. Today there are a few integrated pest management products (IPM) and programs for the treatment of apple scab with various application time. The aim of this study was to identify the optimal application time frame and consolidating it with few treatment programs for dealing with the apple scab disease. For this purpose, were made eight treatment programs comprising several chemical products and were realized in three distinctive treatment periods within the same season. The research is performed amid three years 2015–2017 in one experimental orchard. The formation of the experiment is two factorial randomized block with four replications. The disease infection level was evaluated on 2400 leaves from 98 apple trees. Based on analysed disease index (DI) the treatment programs and periods were compared with each other to conclude with the best combination of fungicides and application period for scab disease management on infected leaves.

Introduction

In the Western Balkans, the apple fruit growers are facing the apple scab disease on yearly basis. Besides the other problems such as instability of climatic conditions (the unexpected frost temperatures on the flowers stage of the apple cultivars, hail, *etc*.), the apple scab disease is causing to them a significant loss in apple production.

Therefore, this disease is remaining the challenge for the local apple grower's community in this region.

Table 1. The yearly apple production (t) in Western Balkans, listed alphabetically (FAOSTAT. *Ministry of Agriculture, Forestry and Rural Development)

Country	2014	2015	2016
Albania	82,060	91,736	101,532
Bosnia	44,795	91,471	69,062
Kosovo*	13,519	18,352	27,485
Macedonia	95,684	136,931	101,088
Montenegro	2,656	2,817	5,541
Serbia	336,313	355,664	328,369

The researchers and agricultural extension services from these countries are trying to come up with the best solutions for the treatment of this disease. One of such contribution is current research, which is performed in the country of Kosovo, which has the moderate expertise for this problem but this research has utilized the latest technology to predict and manage the scab disease infections. In this country, the apple fruit is one of the major crops that is cultivated in commercial orchards. The structure of fundamental cultivars that are in commercial production in the country and region is comprised mainly from Starking, Golden Delicious, Granny Smith, Gala, Idaret, Prima, Topaz but other cultivars such as Jonagold, Fuji, Braeburn, *etc*., are being planted as well. Apple fruit represents approximately 60% of the total number of fruit cultivars in Kosovo. In terms of susceptibility to the diseases and pests, the apple cultivar Starking is extremely touchy.

Apple scab disease is shown in various biological phases. The first infection is started by the discharge of airborne spores. These spores enter the leaf cuticle making the arrangement of a level mycelium between the cuticle and the epidermal cell walls (Delalieux *et* *al*., 2005). The disease of Apple scab which is developed by the pathogen *V. inaequalis* (Cke.) Wint. is a yearly danger to apple cultivation (Carisse *et al*., 2009).

The pathogen *V. inaequalis* is harmful to all blooming organs of the apple crop. The infection is mainly manifested on the leaves and fruits but it also affects the sepals, petioles and blossoms. Dark green or brown spots and lesions, first show up on the leaves not long after bud break. The lesions start on the underside of the leaves, yet are more obvious on the upper side (Jamar, 2011).

When the leaves open, the upper surfaces additionally end up defenceless against disease. An injury initially shows up as a spot which is slightly discoloured than another remaining part of the leaf. The lesion is mainly roundabout and as it increments in a measure it ends up olive-hued and plushy because of the creation of asexual spores (secondary infection). Since the elder leaves are more immune to infection, the lesions that develop on unfolded leaves are commonly minor ones. Lesions that are developed on new leaves might be very expansive, some of them more than 1 cm in distance across. Infected tissues hereafter may end up puckered and contorted and the leaf lesions usually end up torn. The lesions on the fruits and leaves are for the most part rankled and dark brown in appearance with an evident edge (Vaillancourt, Hartman, 2000).

As the infection advances the whole leaf turns up a "messy olive" and tumbles to the ground. In the late spring, these essential infections deliver auxiliary conidia which taint different fruits and leaves. The conidia's may proceed with the infection through the cultivation season among periods of wetness. The pathogen of apple scab does not physiologically ruin the apple tree, but this disease causes numerical reduction of leaves and fruits and numerous vulnerable apple trees by the mid-summer are extremely defoliated (Jamar, 2011). Along these lines, the infection should be controlled with fungicides.

In the event that disease isn't managed, more than 80% of fruits of non-resistant apple cultivars can be harmed. Based on the level of infection, 10 to 15 or considerably more chemical treatments are typically required for effective management (Meszka, 2015).

The frequency of fungicide applications relies upon the source infection mass, the vulnerability of the cultivar and climate conditions, for the most part, leaf wetness, air temperature, precipitation and relative moistness (Gadoury *et al*., 1998, Stensvand *et al*., 1998, Carisse *et al*., 2007).

The overall goal of this study was to develop one treatment program with available IPM products in the country and finding the optimal time frame to realize the fungicide application for managing the primary infections of apple scab. If the primary infections are managed successfully on adequate time in the spring then the secondary infections should be in low level in the summertime. Depending on the weather conditions, especially in dry seasons with temperature increment by the beginning of the summer, the secondary infections in some cases may not require to be treated at all. This research had two main objectives. The first objective was to establish action thresholds for initiation of the spring treatments. The second objective was to combine several fungicides that would perfectly fit in the established treatment period.

Since in the cultivation zone subject of this research, up to now there were not performed any kind of similar studies for apple or pear scab disease, this research is meant to provide useful information for the apple growers and extension services in Kosovo and other western Balkan countries.

Materials and methods

This research has been done amid three years 2015–2017 in location Zhegra (N 42.378998°, E 21.485185°, altitude 550m) in the district of Gjilan, Kosovo.

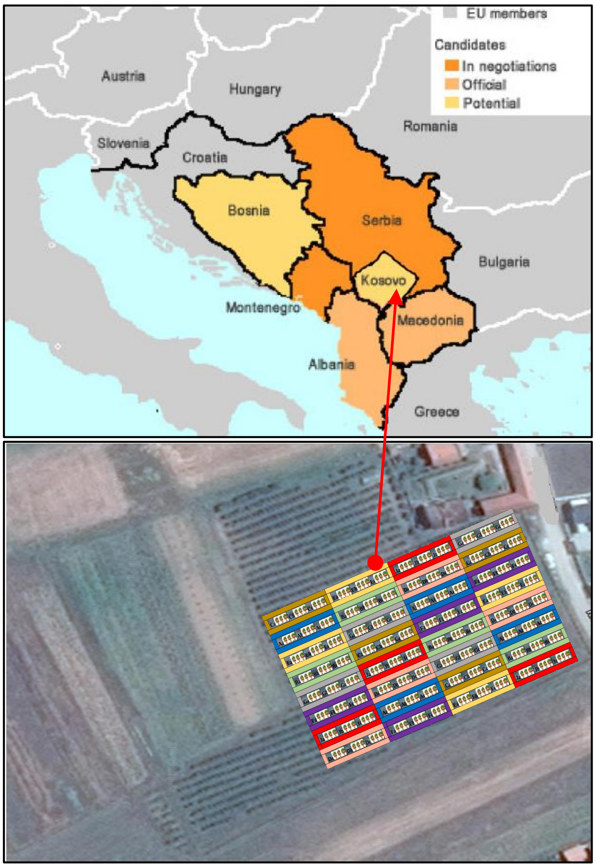

Figure 1. Scheme of experiment and orchard position in the map of Western Balkan countries

In this trial is used the apple Starking cultivar which is known as most susceptible among the other cultivars. The experiment is configured in two factorial randomized blocks with four replications. The experiment is modelled with Factor A for treatment period that has three levels: a) RIMpro period (relative infection measure program); b) Phenological phases' period and c) Local farmers' period.

The RIMpro program is one of the top listed decision support system (DSS) in the Europe which is created by Bio-Fruit-Advies in the Netherlands. This program provides warnings and notices for apple scab infection periods to the farmers and researchers that are associated online, all over the Europe, USA and Canada. The phenological phases' period is, in fact, the apple biological growth stages and for this research are utilized just six phases from the BBCH Scale: 10, 67–69, 71, 72, 74 and 85–87 (Meier, 2001) as shown in Table 2.

The second effect factor (B) is the treatment program in eight levels. The levels consist of different IPM products (Table 4). The product volumes were prepared and mixed as per manufacturer's recommendation on the product label or catalogue for each product. The third effect factor (C) is the treatment years also in three levels: 2015, 2016 and 2017.

The disease severity was determined by rating the scab. The disease severity is a measure of the amount of disease per sampling unit (Nutter *et al*., 2006).

Each treatment program has 9 apple Starking cultivar trees per one replication and for 4 replications there is a total of 36 trees per one treatment program, thus making 288 Starking apple trees for 8 treatment programs (including the non-treated trees). The sampling was performed from the middle trees from the replication blocks (Figure 2). On the 22 July of every research year, there were randomly picked up 25 leaves (all sides of the tree) for evaluation. In the laboratory, 2400 leaves were analysed for the disease index, which was taken from 96 apple trees.

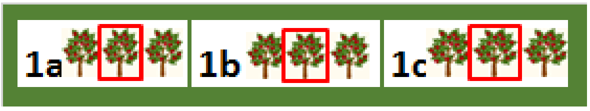

Figure 2. Replication block and sampling tree

For every treatment program, the disease infection level was checked in light of the leaf surface area infected by the pathogen *Venturia inaequalis*.

The infection assessment was defined and classified in the categories of the Standard Area Diagram (SAD). The six SAD categories are presented in percentage from 0% to 75% of the leaf surface infected area as shown in Table 3 (Hasani, 2005) which in fact are modified from 0–9 categories from Lateur and Blazek (2004).

In order to ensure the infection assessment based on SAD was going precisely, Leaf Doctor Software was utilized (Pethybridge and Nelson, 2015) to compare some of the infected leaves.

The disease index (severity) was calculated on 36 apple trees for every treatment program through pondered average with McKinney's index (McKinney, 1923), later modified by B. M. Cooke (Cooke *et al*., 2006).

$$I = \frac{\sum (ni \times ki)}{N \times K} \times 100$$

I = disease index (DI); ni = number of leaves in respective category; ki = number of each category; N = total number of leaves analysed; K = total number of categories.

Table 2. Selected phenological phases' for intervention with fungicides

BBCH Scale	10	67–69	71	72	74	85–87
Phenological Phase						
	Mouse-ear stage: Green leaf tips 10 mm above the bud scales. First leaves separating	Flowers fading: the majority of petals fallen. End of flowering: all petals fell	Fruit diameter size up to 10mm	Fruit diameter size up to 20 mm	Fruit diameter up to 40 mm; fruit erect	Advanced ripening: increase in the intensity of cultivar-specific colour. Fruit ripe for picking

Table 3. Standard Area Diagram (SAD) for apple scab infection assessment on leaves

Leaf						
Category	0	1	2	3	4	5
Intensity level	Nothing noticed	Light intensity	Medium intensity	Strong intensity	Very strong intensity	Destructive intensity
Infection level	0% leaf surface infected	0.1–10% leaf surface infected	10.1–25% leaf surface infected	25.1–50% leaf surface infected	50.1–75% leaf surface infected	> 75% leaf surface infected

Table 4. Treatment programs and dates of application for three years

Program	IPM product	Active substance	Application years/dates 2015	2016	2017
1	Copper hydroxide 50WG	500 g/kg	17.04	21.04	04.04
	Dodine 400SC	400 g/l	27.04, 10.05, 25.05, 10.06	01.05, 15.05, 01.06, 16.06	22.04, 15.05, 31.05, 14.06
2	Copper hydroxide 50WG	500 g/kg	13.04	16.03	20.03
	Captan 80WG	800 g/kg	10.05, 25.05, 08.06, 07.07, 18.08	15.05, 03.06, 18.06, 07.07, 25.08	13.05, 01.06, 16.06, 05.07, 30.08
3	Copper hydroxide 50WG	500 g/kg	10.03	05.03	12.03
	Mancozeb 80WP	800 g/kg	13.04, 25.04, 11.05, 27.05, 13.06, 10.07, 25.08	25.03, 20.04, 10.05, 30.05, 15.06, 05.07, 28.08	20.03, 15.04, 08.05, 28.05, 15.06, 05.07, 15.08
4	Copper hydroxide 50WG	500 g/kg	10.03	05.03	01.03
	Tebuconazole 250EW	250 g/l	13.04, 03.05	25.03, 03.05	20.03, 02.05
	Captan 80WG	800 g/kg	25.05, 01.06, 05.07	01.06, 12.06, 01.07	04.06, 16.06, 05.07
5	Copper hydroxide 50WG	500 g/kg	10.03	05.03	01.03
	Propineb 70WP	700 g/kg	10.05, 25.05	15.05, 01.06	13.04, 01.06
	Difenconazole 250EC	250 g/l	01.06, 07.07, 27.08	16.06, 07.07, 30.08	15.06, 04.07, 25.08
6	Copper hydroxide 50WG	500 g/kg	10.03	05.03	01.03
	Trifloxystrobin 50WG	500 g/kg	13.04, 03.05	25.03, 03.05	20.03, 05.05
	Chlorothalonil 720SC	720 ml/l	01.06, 07.07, 27.08	01.06, 16.06, 05.07	03.06, 19.06, 07.07
7	Copper hydroxide 50WG	500 g/kg	10.03	05.03	01.03
	Cyprodinil 50WG	500 g/kg	13.04, 03.05	25.03, 03.05	20.03, 05.05
	Dithianon 700WG	700 g/kg	01.06, 07.07, 27.08	01.06, 16.06, 05.07	03.06, 19.06, 07.07
8	Control – no treatments	–	–	–	–

The trees in randomized block and other trees in the plantation were treated also with other IPM products for preventive measures against other fungal diseases or pests. Moreover, other agro-technical measures are performed for plantation administration.

The climate conditions in the orchard are measured and gathered by weather station model i-Metos 2 which has configured these parameters: temperature (ºC), relative humidity (RH%), precipitation (mm), dew point (ºC) and two leaf wetness sensors that provide the duration period of the leaf moisture in minutes per 24 hours. One sensor is for the leaves inside the tree wreath and another sensor is for peripheral leaves. This weather station was set up in the middle of the orchard. This station is produced and configured by Pessl Instruments from Austria and monitored by field-climate platform from the same inventor.

The ascospores catching was performed with one spore-trap which is made from the glass and wood material (Ostry and Nicholls, 1982) and was set up in the orchard centre. Afterwards, the glass slides which had one thin layer of Vaseline were observed in the microscope model B120C-E1 AmScope equipped with an advanced camera to distinguish and to take photographs of the captured ascospores in the early spring from the glass slides. The other verification was with visual inspection aiming to discover and confirm the first conidia scabby spots or lesions on the infected apple leaves.

The statistical data analysis for each treatment program respectively the averages and standard deviations are performed with statistical program Assistat, version 7.7. The comparison of mean values was completed with Tukey-Kramer HSD test and diamond plots were completed with Dunnett's test. In both tests, the level of probability is P = 0.05 and the utilized program is SAS/JMP 2009.

Results

In the orchard where this research is performed, the weather conditions such as temperature, precipitation, relative humidity, dew point and leaf wetness duration for three years, basically for the seasonal months that apple scab primary and secondary infections are mostly developed, are presented in below Table 5.

The natural conditions for the development of primary infection from the ascospores and secondary infection from the conidia of fungus *V. inaequalis* in the apple orchard were optimal. The three-month period April-May-June of each year had numerous rainfalls and favourable temperatures and during three years of this research, we had the development of the apple scab infections. The assessment results for disease index on leaves for Starking cultivar, during three research years, are presented in the following table.

The average disease index (DI %) on Table 6, for three years as per RIMpro period varies from 14.67% in P1 which is classified by letter C as per Tukey-Kramer test to 21.40% in P2 and is followed by letter's BC and up to 37.04% in control group of non-treated trees which is classified by letter A. The average disease index measured for three years as per phenological phases' period begins with 17.31% in P1 which is classified with letter C and then is followed by letter BC in second treatment program with DI value of 22.93% and up to 37.88% in control variant followed by letter A. Additionally, the average disease index for local farmers' period for three years starts with 19.97% in P1 classified with letter B then is followed by same letter B with DI value of 25.47% in 2nd treatment program and up to 37.98% in the control variant followed by letter A. Tukey-Kramer test show that there are statistically significant differences between the treatment programs in the three periods of treatment.

The One-Way Analysis of Variance (ANOVA) for evaluation of the apple scab disease index (DI %) on the leaves for three years that is presented in Table 7, shows statistically proven differences between the treatments programs in all treatment periods. In the case of RIMpro, F Ratio is 12.5209; P < 0.0001, Phenological phases F Ratio = 7.8739; P = 0.0003 and Local farmer F Ratio = 6.5240; P = 0.0009.

Table 5. Monthly weather data for three years 2015, 2016 and 2017 measured on the experimental apple orchard

Months/Years	T ºC Max.	T ºC Avg.	T ºC Min.	RH% Max.	RH% Avg.	RH% Min.	Rain (mm)	Dew Point T ºC Avg.	Leaf wetness inside tree wreath (min)	Leaf wetness peripheral leaves (min)
Feb. 2015	17.2	2.63	–11.3	94.23	74.26	15.20	67.60	–1.2	10,045	11,120
Feb. 2016	23.5	8.07	–5.6	94.73	73.48	26.10	50.60	2.8	9,760	12,010
Feb. 2017	19.5	4.08	–6.5	94.15	75.90	21.90	38.80	0.3	5,580	13,365
March 2015	17.2	8.76	–4.5	98.30	75.85	47.01	104.00	0.5	19,080	19,580
March 2016	24.9	8.73	–4.9	97.56	73.96	39.67	123.20	1.8	13,210	14,935
March 2017	26.9	10.48	–2.8	92.34	63.00	23.58	21.20	1.1	7,115	20,915
April 2015	24.9	11.92	–2.1	91.88	59.95	26.29	46.00	1.2	8,490	8,785
April 2016	33.2	15.31	–1.3	96.45	62.37	25.11	37.00	5.4	3,965	5,290
April 2017	30.4	12.62	–3.5	97.29	63.68	31.23	66.80	2.7	4,235	6,585
May 2015	33.9	18.38	3.7	96.45	66.81	32.30	37.00	9.6	10,555	9,605
May 2016	31.8	14.23	1.5	99.26	75.08	35.62	117.20	8.9	14,895	18,505
May 2017	32.8	17.37	2.1	100.00	74.76	31.38	102.00	9.8	5,715	5,435
June 2015	33.7	20.30	6.9	96.25	67.97	30.43	56.00	11.3	11,570	8,125
June 2016	37.9	22.51	8.6	98.48	69.04	31.62	84.2	13.5	6,125	8,705
June 2017	39.2	22.27	6.8	100	72.66	25.20	82.4	13.9	5,500	4,200
July 2015	37.3	24.20	9.1	95.52	58.04	24.16	11.0	13.1	3,420	1,545
July 2016	37.5	23.63	8.6	97.97	66.45	29.39	96.8	14.0	5,185	4,865
July 2017	42.1	25.10	8.0	97.64	59.37	21.91	19.2	11.8	2,145	790
Aug. 2015	36.7	24.35	11.3	91.67	59.07	23.90	44.0	12.5	5,440	4,150
Aug. 2016	35.9	21.71	5.7	98.91	71.69	33.06	58.2	13.6	5,735	5,505
Aug. 2017	42.7	24.73	5.5	97.95	57.40	14.39	54.8	10.6	2,545	1,945

Table 6. Disease Index (DI %) data analysed on apple leaves for eight treatment programs realized in three treatment periods for three years (2015–2017).

Treatment Programs	Treatment Periods											
	RIMpro (a)				Phenological phases (b)				Local farmer (c)			
	DI % per program/year			Average	DI % per program/year			Average	DI % per program/year			Average
	2015	2016	2017		2015	2016	2017		2015	2016	2017	
P1	15.50	16.50	12.0	14.67 C	18.63	20.25	13.05	17.31 C	21.13	22.93	15.85	19.97 B
P2	22.50	22.58	19.13	21.40 BC	23.25	25.30	20.25	22.93 BC	25.25	28.65	22.50	25.47 B
P3	27.00	27.78	22.38	25.72 B	28.75	30.10	24.28	27.71 B	30.00	31.63	26.13	29.25 AB
P4	23.00	22.58	20.13	21.90 BC	25.00	26.88	22.13	24.67 BC	26.13	27.95	23.63	25.90 B
P5	23.50	24.60	20.75	22.95 BC	26.00	28.45	23.10	25.85 BC	27.88	29.50	24.00	27.13 B
P6	24.25	23.63	20.93	22.94 BC	25.63	27.50	22.38	25.17 BC	26.50	27.53	23.63	25.88 B
P7	23.25	24.88	20.63	22.92 BC	25.13	27.35	22.15	24.88 BC	27.13	29.15	24.08	26.78 B
Control	40.25	41.38	29.50	37.04 A	40.63	42.75	30.25	37.88 A	40.75	42.38	30.75	37.98 A
Avg.	24.91	25.49	20.68	23.69	26.63	28.57	22.20	25.80	28.09	29.96	23.82	27.29

LSD = 3.46215 for @ 0.05

The Tukey-Kramer test at a level of 5% of probability was applied. The averages not connected by the same letter are significantly different.

Table 7. One-Way Analysis of Variance (ANOVA) for disease index on leaves for eight treatment programs realized in three treatment periods for three years (2015–2017)

Treatment period	Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
	Treatments	7	821.94576	117.421	12.5209	<0.0001*
RIMpro	Error	16	150.04793	9.378		
	C. Total	23	971.99370			
	Treatments	7	696.96210	99.5660	7.8739	0.0003*
Phenological phases	Error	16	202.32060	12.6450		
	C. Total	23	899.28270			
	Treatments	7	536.34778	76.6211	6.5240	0.0009*
Local farmer	Error	16	187.91220	11.7445		
	C. Total	23	724.25998			

The diagram of means diamonds in Figure 3, provides the pairwise comparison between the treatment programs with the control group for apple scab disease management on infected leaves as per RIMpro period of treatments. The treatment programs with grey circles and italicized variable labels, such programs as from 1 to 7 are significantly different from the control program P = 0.05, as per Dunnett's test. The treatment programs from 1 to 7, except the program 3, are below the overall average which in this case for the RIMpro period is 23.9. The untreated apple trees from the control group are presented with a red circle and red variable label and their mean are above the overall average (horizontal centre line of the diamond/circles plot).

The graphic in Figure 3 shows that program 1 has the lowest DI followed by program 2 and 4. As per Tukey-Kramer HSD, there are also statistically significant differences between the treatment programs but only for program 3 and 1, the difference is 11.05 and P = 0.0079. The other pair comparisons between the treatment programs were not statistically different.

The pairwise comparison between the treatment programs with the control group as per phenological phases treatment period is presented by the diagram of diamonds and comparison circles plot in Figure 4. The treatment programs with grey circles and italicized variable labels respectively the programs from 1 to 7 are significantly different from the control variant for the level of probability P = 0.05, as per Dunnett's test. Tukey Kramer HSD pair comparisons show that there are statistically significant differences between the control variable and treatment programs during phenological phase's treatment. Pair comparisons between the 7 treatment programs show statistically significant differences only between program 3 and program 1, the difference is about 10 and P = 0.0399*.

The comparison among the treatment programs for apple scab disease management on infected leaves according to the local farmers' period of treatment is provided in Figure 5. The treatment programs with grey circles such programs as 1, 2, 4, 5, 6 and 7 are significantly different from the control group for the level of probability P = 0.05, as per Dunnett's test. The means of these 6 treatment programs are below the overall average which in this treatment period is 27.1. The Tukey-Kramer HSD pair comparisons show that there is the statistically significant difference between the treatment period and treatment programs. Only the program 3 and control do not show any statistical difference P = 0.06. Pair comparison between the treatment programs does not show any significant statistical difference.

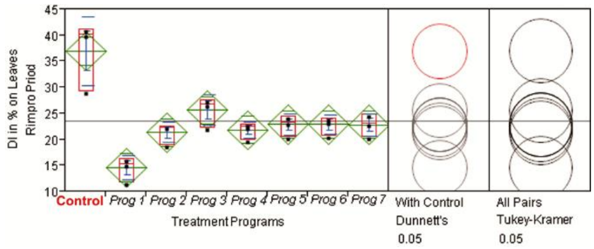

Figure 3. Diagram of means diamonds (diamond plot) and comparison circles plot for the RIMpro period.

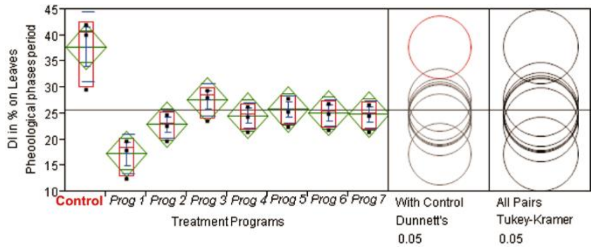

Figure 4. Diagram of means diamonds (diamond plot) and comparison circles plot for phenological phases period

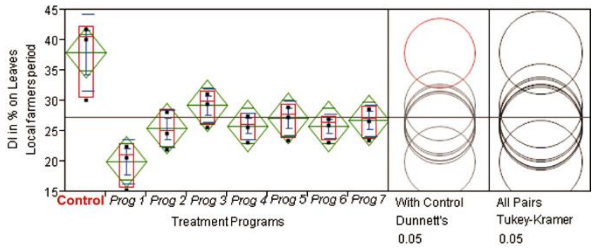

Figure 5. Diagram of means diamonds (diamond plot) and comparison circles plot for Local farmer's period.

The three-factorial Analysis of Variance (MANOVA) for the apple scab disease index (DI %) assessment on leaves for three years that is presented in Table 8, proved that this disease is influenced by a few factors. This analysis proves that all treatment factors are statistically significant. The effect of factor A (treatment years) has empirical F value of 353.79**. This value is significantly higher than theoretical F value 3.04 for the level of 5% of probability.

Table 8. Three factorial Analysis of Variance (MANOVA) for disease index (DI%) on leaves for eight treatment programs realized in three treatment periods for three years.

Sources of Variation	DF	SS	MS	F Values	
				Empirical	Theoretical 95%
Treatment Years (A)	2	1,729.00340	864.50170	353.79**	3.04
Treatment Periods (B)	2	632.27549	316.13774	129.37**	3.04
Treatment Programs (C)	7	8,145.80774	1,163.68682	476.24**	2.06
Interaction AxB	4	27.49535	6.87384	2.81*	2.42
Interaction AxC	14	383.39215	27.38515	11.20**	1.74
Interaction BxC	14	79.85340	5.70381	2.33**	1.74
Interaction AxBxC	28	19.16076	0.68431	0.28 ns	1.53
Total treatments	71	11,016.98830	155.16885	63.50**	1.36
Error	216	527.79250	2.44348	–	–
Variation total	287	11,544.78080	–	–	–

The effect of factor B, the treatment periods (three different periods of time), has empirical F value of 129.37** which is also much higher than theoretical F value for the level of 5% of probability.

Likewise, the effect of factor C, the treatment programs (eight programs with different IPM products), have factual F value of 476.24** which is also much higher than theoretical F value, such value as 2.06 for the level of 5% probability.

The effects of interaction between the treatment years and treatment periods in three years of treatment are valued for empirical F as 2.81* and this resulted to be a little bit higher than theoretical F value for P = 0.05 which is 2.42. The effects of interaction between the treatment years and treatment programs are valued at 11.20** also this resulted to be higher than theoretical F value for P = 0.05 which is 1.74. The effects of interaction between other two factors respectively the treatment periods and treatment programs (BxC) is valued at 2.33** and this also resulted to be higher than theoretical F value 1.74 for P = 0.05.

Lastly, the interaction between all treatment factors (AxBxC) resulted in factual F value of 0.281ns which is lower than theoretical F value for the level of 5% of probability. Therefore, the interaction between all three factors practically had no significant effect in regards to the protection of scabby apple leaves.

Discussion

Scab *(V. inaequalis)* normally occurs every year wherever apple trees are cultivated in Kosovo and other countries in the region. The scab issues are studied from other researchers in the western Balkans. In the country of Albania, the Skenderasi *et al*. (2013) in the region of Korça with similar weather conditions with the region where this research is conducted, has checked in few times the effectiveness of some fungicides for controlling the apple scab based on the level of infection. In Serbia, the Djordevic *et al*. (2013) has tested the resistance and tolerance of some apple cultivars to the apple scab disease. Again, in Albania, Marku *et al*. (2014) in the region of Puka has evaluated the effectiveness of bicarbonates used alone or combined with horticultural oils to fight the apple scab based on evaluated disease index. Balaz *et al*., (2017) has evaluated the reactions of some apple cultivars to *V .inaequalis* and other diseases under natural infection in Serbia. The results showed that for three years 2015–2017, based on the comparison of three annual DI averages on Table 6, for a RIMpro treatment period, the year 2017 had the lowest annual disease index average comparing to the other two years. This is same also in other two treatment periods, the year 2017 had the lowest annual average disease index. This could be due to the strict regime of fungicide treatment that is performed on trial apple trees and the orchard in overall for the third year in a row. Also, based on the comparison of DI averages from all treatment programs realized in all treatment periods in all three treatment years which are presented in Table 6, it resulted that treatment program one has the lowest DI average than any other treatment program. This seems is due to the effects from the fungicide combination of Copper hydroxide and Dodine which has provided the best protection of leaves from the scab infection. The One-Way Analysis of Variance (ANOVA) shows that RIMpro treatment period has the biggest statistical difference comparing to other two treatment periods. Also, based on the mean comparison in all three diamond plots presented in Figures 3–5, evidently is seen that the first treatment program which is realized based on the predictions that were provided by DSS RIMpro, had the lowest mean in all three treatment periods.

Pair comparisons between the 7 treatment programs on the phenological phases period show statistically significant differences only between program 3 and program 1, the difference is about 10 and P = 0.0399*. This could be due to the fungicide Mancozeb which is used in a third treatment program and is used more than any other fungicide has not provided good protection from *V. inaequalis*. Based on the MANOVA presented on Table 8, the effect of interactions between all treatment factors is statistically non-significant, practically the small difference of climatic conditions in three different treatment years has not affected the other effects that were derived from treatment programs realized in three different periods and therefore did not change anything significantly in regards to the protection of apple leaves from the scab infection.

Conclusion

Based on the disease index assessed on leaves for three years, it appeared that IPM products from the first treatment program provided the best protection of leaves from the apple scab. This program had also the lowest number of spraying applications comparing to other programs. This protection became possible because the treatments were performed based on the accurate warnings for scab infection periods that were received from DSS RIMpro. Therefore, the RIMpro period proved to be the best treatment period for all treatment programs execution.

The second treatment program realized through the treatment period of six phenological phases of the apple tree can be seriously considered to be utilized by the apple growers in this area. Especially those farmers that do not have the possibility to be connected and to interact with any decision support system provided by extension services.

The year 2016 had the highest disease index on leaves in all treatment periods. The local farmer period had the highest disease index average of 29.96% for the year 2016 and the highest disease index average of 27.29% for all three years. This means that those farmers that continue to protect the apple tree based on their own expertise need to be brought together to interact with each other and utilize the help and support from extension services.

Besides the actual traditional apple cultivars with the domination of Starking in Kosovo and overall in the region of Western Balkans, other cultivars resistant to scab infection such as Winesap, Liberty and Jonathan should be imported and planted as well.

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Conflict of interest

The authors declare that they do not have any conflict of interest.

Author contributions

ER initiated the research (concept and design), worked on the orchard and acquisition data. HP supervised and provided the advice for the research. HV and EK performed statistical analysis and interpretation. AH drafted the manuscript and assisted the ER with the laboratory work.

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Appendix

Figures caption for Figures 3 to 5

The top and bottom points of green diamonds are the confidence intervals (CI) as a supplement to the P-value with 95% confidence interval for each mean. The green centre line presents the mean, the width of the diamond is proportional to the size of sample group. The red boxes represent the distribution, three blue dots per diamond represent the DI values for three treatment years and the lower/upper horizontal blue lines are the standard deviation. The grey and red circles represent the means comparison between the treatment programs. The grey circles with italicized variable labels are for the programs that are significantly different from the control group. The black horizontal centre line of the diamond and circles plot is the overall average of the disease index (DI).

Tables as additional attachments to diamond plots

Table 1. Pair comparisons for RIMpro treatment period presented in diamonds plot

Level	– Level	Difference	Std. err. dif.	P-value	Difference
Control	Prog. 1	22.37667	2.500399	<0.0001*	
Control	Prog. 2	15.64000	2.500399	0.0002*	
Control	Prog. 4	15.14000	2.500399	0.0003*	
Control	Prog. 7	14.12333	2.500399	0.0007*	
Control	Prog. 6	14.10667	2.500399	0.0008*	
Control	Prog. 5	14.09333	2.500399	0.0008*	
Control	Prog. 3	11.32333	2.500399	0.0064*	
Prog. 3	Prog. 1	11.05333	2.500399	0.0079*	

Table 2. Pair comparisons for Phenological phase's treatment period presented in diamonds plot

Level	– Level	Difference	Std. err. dif.	P-value	Difference
Control	Prog. 1	20.56667	2.903451	<0.0001*	
Control	Prog. 2	14.94333	2.903451	0.0019*	
Control	Prog. 4	13.20667	2.903451	0.0061*	
Control	Prog. 7	13.00000	2.903451	0.0071*	
Control	Prog. 6	12.70667	2.903451	0.0086*	
Control	Prog. 5	12.02667	2.903451	0.0136*	
Prog. 3	Prog. 1	10.40000	2.903451	0.0399*	
Control	Prog. 3	10.16667	2.903451	0.0464*	

Table 3. Pair comparisons for Local farmers treatment period presented in diamonds plot

Level	– Level	Difference	Std. err. dif.	P-value	Difference
Control	Prog. 1	17.99000	2.798156	0.0002*	
Control	Prog. 2	12.49333	2.798156	0.0072*	
Control	Prog. 6	12.07333	2.798156	0.0097*	
Control	Prog. 4	12.05667	2.798156	0.0098*	
Control	Prog. 7	11.17333	2.798156	0.0181*	
Control	Prog. 5	10.83333	2.798156	0.0229*	
Prog. 3	Prog. 1	9.28333	2.798156	0.0654	
Control	Prog. 3	8.70667	2.798156	0.0950	